ISSN 0008-3194 (p)/ISSN 1715-6181 (e)/2015/253–260/$2.00/©JCCA 2015

A rare case of unilateral variations of forearm arteries: anatomy, embryology and clinical implications

Myroslava Kumka, MD, PhD[1]
Sheila Purkiss, BSc, MSc[1]

This study documents the existence and topographic anatomy of a rare case of variant forearm arteries found in the left upper limb of a 68-year-old male cadaver. The arteries of the arm followed typical courses, but both the radial and ulnar arteries in the forearm followed a superficial course. The common interosseous artery and recurrent ulnar arteries branched from the radial, not the ulnar, artery. The radial artery was larger than the ulnar artery and was the major source of blood supply to the forearm. Clinical implications for single superficial forearm arteries are reviewed. A person with both superficial radial and superficial ulnar arteries would be at a substantially increased risk of injury or iatrogenic effects that could compromise blood supply to the hand. This study will enhance clinician's awareness of potential arterial variations, so they can provide

Cette étude documente l'existence et l'anatomie topographique d'un rare cas de variante d'artères de l'avant-bras observé dans le membre supérieur gauche du cadavre d'un homme de 68 ans. Les artères du bras ont suivi des trajets typiques, mais les artères radiale et cubitale de l'avant-bras ont suivi un trajet superficiel. L'artère interosseuse commune et les artères cubitales récurrentes se sont ramifiées à partir de l'artère radiale, pas l'artère cubitale. L'artère radiale était plus grande que l'artère cubitale et elle était la principale source d'approvisionnement en sang à l'avant-bras. Les effets cliniques d'artères simples superficielles de l'avant-bras sont examinés. Une personne dont les deux artères radiale et cubitale sont superficielles serait à un risque considérablement accru de blessures ou d'affection iatrogène qui pourraient diminuer l'approvisionnement en sang à la main. Cette étude permettra de sensibiliser davantage les cliniciens aux variations artérielles potentielles, de sorte qu'ils puissent offrir une

[1] Department of Anatomy, Canadian Memorial Chiropractic College, Ontario, Canada.

Corresponding author: Myroslava Kumka
mkumka@cmcc.ca
Department of Anatomy, Canadian Memorial Chiropractic College, 6100 Leslie Street, Toronto, ON M2H 3J1
T: (416) 482-2340 ext 175

adequate assessment, diagnosis and treatment of upper limb lesions.

(JCCA. 2015;59(3):253-260)

KEY WORDS: radial artery, ulnar artery, arterial variations, arterial development, ultrasonography, diagnosis, chiropractic

évaluation, un diagnostic et des traitements adéquats des lésions des membres supérieurs.

(JCCA. 2015;59(3):253-260)

MOTS CLÉS : artère radiale, artère cubitale, artère ulnaire, variations artérielles, développement artériel, échographie, diagnostic, chiropratique

Introduction

Variations in upper limb arteries are a source of great interest since they provide insight into individual development and can affect both diagnosis and treatment.[1,2] Reviewing the literature, we found the variations in the arterial pattern of the upper limb are common and have long received attention from anatomists and clinicians.[3-14]

It is important that surgeons, chiropractors, and other medical professionals are aware of variations in the course of the forearm arteries that can affect both symptoms and diagnoses. These variations can affect the interpretation of morphological and functional findings, or lead to difficulty interpreting angiographic images.[15-20] They can directly affect the success, and complication rates of procedures, such as cannulation, radial forearm flap surgery, arterial grafting, fasciotomy for compartment syndrome, cardiac catheterization, angioplasty, and orthopaedic surgery.[6,7,10,12,16,17,19-31]

It is especially important to understand these variations in order to avoid misdiagnosing forearm pathology, as described by McWilliams et al[27], when a variant superficial ulnar artery was clinically mistaken for phlebitis. Also of note is the increased vulnerability of superficial arteries to injury and laceration.[14,20,32]

The purpose of the presented study is to document the existence and topographic anatomy of a case of variant forearm arteries. We hope our study helps to enhance clinician's awareness of potential arterial variations, so they can then provide adequate assessment, diagnosis and treatment of upper limb lesions.

Materials and Methods

During a routine dissection of the upper limbs of a 68-year-old male cadaver, atypical courses and branching pattern of the left forearm arteries were encountered. These variant arteries were followed and their features documented and photographed.

Results

Both variant forearm arteries in the left upper limb arose from a typical brachial artery. As is usual, the brachial artery was at first medial to the humerus, and then gradually spiralled anterior to it, reaching the midpoint of the cubital fossa, lateral to the median nerve. Within the cubital fossa the brachial artery was located centrally and divided near the neck of the radius into its terminal branches, the radial and ulnar arteries. We observed a variant course for the ulnar artery, and a variant course and unusual branching pattern for the radial artery (Figure 1A).

Ulnar artery

The ulnar artery, as one of the two terminal branches of the brachial artery, was smaller than is commonly seen. In typical cases, the ulnar artery is the larger terminal branch of the brachial artery.[4,14] The variant ulnar artery descended through the entire forearm superficially, covered only by the skin, subcutaneous tissue and the antebrachial fascia. For this reason, we classified it as a superficial ulnar artery (SUA).

The course of the SUA with respect to the median nerve was also of note. Distal to the elbow, the SUA followed the usual course lateral to the median nerve, then crossed superficial to the median nerve, but was separated from it by the humeral head of the pronator teres muscle (Figure 1B). In the typical course, the ulnar artery crosses deep to the median nerve and is separated from it by the ulnar head of the pronator teres muscle.[4,14] On its course from the cubital fossa to the medial side of the forearm midway between the elbow and wrist, the SUA descended superficial to the pronator teres, flexor digitor-

Figure 1.
Topography of the variant radial and ulnar arteries.

LEGEND
1 – brachial artery
2 – median nerve
3 – pronator teres muscle: humeral head
4 – ulnar artery
5 – radial artery
6 – brachioradialis muscle
7 – flexor digitorum superficialis muscle
8 – flexor carpi radialis muscle
9 – common interosseous artery

Figure 1A. Illustration of the superficial course of the variant ulnar and radial arteries in the anterior forearm region. The variant ulnar artery (4) is the smaller terminal branch of the brachial artery (1) and descends superficial to the forearm flexors. The variant radial artery (5) is the larger terminal branch of the brachial artery and runs superficial along its course in the forearm.

Figure 1B.
The variant ulnar artery (4) crosses superficial to the median nerve (2), but is separated from it by the humeral head of the pronator teres muscle (3). The common interosseous artery (9) in this case, is the branch of the radial artery (5).

um superficialis and flexor carpi radialis muscles (Figure 1A). In typical cases, the ulnar artery passes deep to these muscles.[4,14]

The distal half of the SUA, from the level of the mid-forearm to wrist, follows a typical course for the ulnar artery: at the wrist it was accompanied medially by the ulnar nerve and the tendon of the flexor carpi ulnaris, then traversed the superficial part of the flexor retinaculum, and continued across the palm as the superficial palmar arterial arch. The comparison of the courses of the variant SUA and the typical ulnar artery is provided in Table 1.

Table 1.
Comparison of the courses of the variant superficial ulnar artery (SUA) and the typical ulnar artery.

Course & features	Typical ulnar artery[4,14]	Variant SUA
Origin	Larger terminal branch of the brachial artery.	Smaller terminal branch of the brachial artery.
Forearm's proximal half	Passes deep to the pronator teres, flexor digitorum superficialis, and flexor carpi radialis muscles.	Passes superficial to the pronator teres, flexor digitorum superficialis, and flexor carpi radialis muscles. It is covered by the skin, subcutaneous tissue and antebrachial fascia.
Relationship to median nerve	Lateral to the median nerve, and then it crosses deep to the median nerve, but is separated from it by the ulnar head of the pronator teres.	Lateral to the median nerve, and then it crosses superficial to the median nerve, but is separated from it by the humeral head of the pronator teres muscle.
Forearm's distal half, wrist and hand	Covered by the skin, subcutaneous tissue and antebrachial fascia. Lateral to the flexor carpi ulnaris tendon and ulnar nerve. Traverses the superficial layer of the flexor retinaculum and continues across the palm as the superficial palmar arterial arch.	Follows the typical course.

Radial artery

Contrary to what is typically seen, the radial artery in this case was the main branch of the brachial artery, and was therefore larger than usual. The course of a typical radial artery in the proximal forearm is deep to the belly of the brachioradialis muscle, and in the distal forearm it is more superficial, covered only by skin and antebrachial fascia.[4,14] In our subject the radial artery was covered only by skin and antebrachial fascia along its course in the forearm and did not run deep to the brachioradialis (Figure 1A). For this reason, we classified it as a superficial radial artery (SRA). Unlike most of the reported superficial radial arteries,[4,6,14,18,33-35] the superficial radial artery in our subject followed a typical course in the wrist by running deep to the extensor tendons at the level of the anatomical snuff box.

We also found an atypical branching pattern of the radial artery. The common interosseous artery, which usually arises from the ulnar artery, in this case emerged as a short branch of the radial artery distal to the radial tuberosity (Figure 1B). While passing toward the interosseous membrane, the common interosseous artery was separated from the median and anterior interosseous nerves by the ulnar head of the pronator teres muscle (Figure 2). The common interosseous artery gave off the anterior interosseous artery and the anterior and posterior ulnar recurrent arteries before continuing across the interosseous membrane as the posterior interosseous artery. All of these branches followed typical courses and supplied the major part of the posterior and anterior muscular compartments of the forearm region.[4,14]

Discussion

Since the presence of both a superficial ulnar and a superficial radial artery in one arm is extremely rare, we will first discuss the incidence of the better documented singly occurring superficial forearm arteries. We will then discuss the two studies in which both forearm arteries were superficial, and the clinical implications of this type of variation.

Superficial ulnar arteries are relatively rare, 0.7% to 9.4%.[6,14,30] However, they usually branch much higher, either from the axillary artery or the brachial artery as it courses in the arm, and are classified as superficial brachioulnar arteries.[6] The superficial ulnar artery in our subject originated in the cubital fossa, so would not meet the definition of a brachioulnar artery.

Superficial radial arteries are even more rare, at an

Figure 2.
The relationship of the common interosseous artery with the median and anterior interosseous nerves and with the ulnar head of the pronator teres muscle.

The common interosseous artery (7), branch of the radial artery (6), divides into the anterior (9) and posterior interosseous arteries. The ulnar head of the pronator teres muscle (2) separates the common interosseous artery (7) from the median (3) and anterior interosseous (10) nerves. The anterior (8) and posterior ulnar recurrent arteries are the branches of the common interosseous artery.

LEGEND
1 – pronator teres muscle: humeral head
2 – pronator teres muscle: ulnar head
3 – median nerve
4 – brachial artery
5 – ulnar artery
6 – radial artery
7 – common interosseous artery
8 – anterior ulnar recurrent artery
9 – anterior interosseous artery
10 – anterior interosseous nerve

incidence rate of ~0.5%, although this varies by population.[6,36,37] They most often occur at the level of the anatomical snuff box, with the artery passing superficial to the tendons that form the borders of the snuff box, rather than deep to them.[4,6,14,33] The superficial radial artery in our subject differed from this pattern since it originated in the cubital fossa, was superficial along the forearm, and followed a typical course deep to the tendons that border the anatomical snuff box.

Rodriguez-Niedenfuhr et al.[6], described a superficial brachioulnoradial artery as a superficial brachial artery branching at the elbow into radial and ulnar arteries and coexisting with a typical brachial artery that continues as the common interosseous trunk. This is a different variation than in our study where the brachial artery followed a typical course with just the radial and ulnar arteries following a superficial course.

The incidence of a combined superficial radial artery and superficial ulnar artery is far less than the incidence singly. We have only found two case reports where both a superficial radial and a superficial ulnar artery occurred in the forearm, and only one of these subjects had an abnormal branching pattern of the radial artery.[32,38] In both of these studies the subjects had a superficial brachial artery with many branches, but did not have a typical brachial artery. In these cases the superficial radial and superficial ulnar

artery arose from the bifurcation of a superficial brachial artery in the cubital fossa. This was different than in our study, where the SRA and SUA arose from a typical brachial artery. Similar to our study, the superficial radial and superficial ulnar arteries rejoined their "common textbook" position in the distal forearm. In one subject the common interosseous artery arose from the radial artery, but this subject also had a median artery originating from the common interosseous artery. In both of these studies there were variant arteries along most of the upper limb, both in the arm and forearm. Our study demonstrates that it is possible to have variant forearm arteries occurring with typical arm arteries. Despite this being a rare variant, the risk of injury and iatrogenic consequences that could impact blood supply to the hand are substantially higher than the risks associated with the more frequently reported single superficial forearm arteries. The clinical implications relating to a single SUA or SRA will be combined to discuss the clinical implications of the variants described in this study.

An awareness of these variations is essential in order to prevent difficulty in performing physical exams, or interpreting physical findings. McWilliams et al.[27], presented a case in which a superficial ulnar artery was misdiagnosed as phlebitis. Chin et al.[15], described the difficulty even trained anaesthesiologists have in differentiating between an artery and vein in a case when a superficial ulnar artery is present. In the current study this difficulty would be compounded by the difference in size of the radial and ulnar arteries, with the radial being larger than usual, and therefore having a relatively stronger pulse.

Clinical difficulties associated with superficial brachioulnar arteries and superficial radial arteries have been separately reported. These include inadvertent cannulation and difficulty interpreting angiographic images.[2,9,19,30] Due to its position close to the cephalic vein, a superficial radial artery is at greater risk of being accidentally cannulated than a superficial ulnar artery.[15] Surgery for radial forearm flaps, coronary bypass and compartment syndrome could lead to accidental division of the artery, which could jeopardize blood flow to the hand.[1,6,15,16,18,23-29,30,35] On the contrary, if the superficial brachioulnar artery is identified, it could actually be of benefit for plastic surgeons performing reconstructive surgery with skin flaps, since it potentially has lower complication rates and better cosmetic outcome than radial forearm flaps.[6,30]

The frequent use of the radial artery in coronary and forearm flap procedures makes preoperative identification of the arterial path by Doppler ultrasound or angiography important.[9,17,18,20,22,27,31] With the variant arteries described in this study this would be even more vital, since the radial artery was the main source of blood supply to the hand.

The clinical implications that were discussed above with regard to superficial brachioulnar and superficial radial arteries would also apply to our subject. The argument could be made that since both forearm arteries are superficial, a person with these variations is at much greater risk for an injury that could compromise blood supply to the hand.

Different theories about arterial development in the upper limb have been a source of controversy for many years.[39] When we combine the information from studies that analysed embryonic development using 3D reconstructive imaging[40] with information from molecular and genetic studies[41], a more comprehensive picture of arterial development emerges.

Vasculogenesis occurs when signalling pathways cause hemangioblasts and endothelial cells to assemble into primitive tubular networks. The cells involved further differentiate into arterial and venous endothelial cells, creating the primary capillary plexus. This primary capillary plexus is transformed into a complex network by a remodelling and sprouting process called angiogenesis. A delicate balance between activators and inhibitors in the signalling pathways controls vessel formation during angiogenesis. The capillary plexus develops in a proximal to distal pattern and is present in the entire upper limb by the 28th day of human embryonic development.

At this point the capillary plexus begins a maturation process involving the proximal to distal differentiation of selected parts. Some of the capillary plexus is maintained, some enlarged, and some is pruned in response to the demands of specific tissues and organs. Oxygenation and nutrient availability may play a role in the expression of the genetic pathways controlling this process. The axillary and brachial arteries are present by the 41st day, and the branches of the forearm arteries are present, except the distal radial artery, by the 44th day of human embryonic development. The variant arteries found in our subject indicate that a disruption occurred during the process of

vessel formation sometime between the 41st and 44th days of human embryonic development.

Conclusions

We present an unusual case of superficial radial and ulnar arteries. Typically variations in forearm arteries are associated with early branching from the brachial artery, or, in the case of the radial artery, a superficial course distally in the forearm and wrist. In the presented case the brachial artery bifurcates as usual in the cubital fossa, but both radial and ulnar arteries are superficial for the length of the forearm, then they resume typical paths as they cross the wrist. Also of note in this case, the common interosseous artery emerged as a branch of the radial artery, not the ulnar. To our knowledge, this combination of variations has not previously been reported. A person with these variations is at much greater risk of injury affecting blood supply to their hands, and of iatrogenic complications if invasive procedures are undertaken without identifying the variations beforehand.

References

1. Bergman RA, Thompson SA, Afifi AK. Catalog of Human variation. Baltimore-Munich: Urban & Schwazzenberg, 1984: 103-112.
2. Ciervo A, Khan M, Pangilinan AJ, Dardik H. Absence of the brachial artery: Report of a rare human variation and review of upper extremity arterial anomalies. J Vasc Surg. 2001; 33(1): 191-194.
3. McCormack LJ, Cauldwell EW, Anson J. Brachial and antebrachial arterial patterns. Surg Gynecol Obstet. 1953;96:43-54.
4. Williams PL, ed. Gray's Anatomy. The Anatomical basis of Medicine and Surgery.38th ed. Edinburgh: Churchill Livingstone, 1995; 1538-1544.
5. Mordick TG. Vascular variation of the radial forearm flap: a case report. J Reconstr Microsurg. 1995; 11(5): 345-346.
6. Rodriquez-Niedenfuhr M, Vazquez T, Nearn L, Ferreira B, Parkin I, Sanudo JR. Variations of the arterial pattern in the upper limb revisited: a morphological and statistical study, with review of the literature. J Anat. 2001; 199(Pt 5): 547-566.
7. Gabe ED, Figal JC, Wisner JN, Laguens R. Radial artery graft vasospasm. Eur J Cardiothorac Surg. 2001; 19: 102-104.
8. Porter CJ, Mellow CG. Anatomically aberrant forearm arteries: an absent radial artery with co-dominant median and ulnar arteries. Br J Plast Surg. 2001; 54(8): 727-728.
9. Connel DA, Koulouris G, Thorn DA, Potter HG. Contrast-enhanced MR angiography of the hand. Radiographics. 2002; 22(3): 583-599.
10. Patterson RB, Smail D. Radial artery as conduit for distal renal artery reconstruction. J Vasc Surg. 2003; 38(3): 609-612.
11. Loukas M, Curry B. A case of an atypical radial artery. Clin Anat. 2006; 19(8): 706-707.
12. Kohonen M, Teerenhovi O, Terho T, Laurikka J, Tarkka M. Forearm vessel atherosclerosis. A harbinger of carotid disease? Scand Cardiovasc J. 2009; 43(1): 69-71.
13. Klimek-Piotrowska W, Pacholczak R, Walocha J. The multiple variations of the arterial pattern in upper extremities: A case report and embryological pathogenesis. Clin Anat. 2012; 26: 1031-1035.
14. Moore KL, Dalley FD, Agur AMR. Clinically oriented anatomy.7th. ed. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins, 2014: 670-819.
15. Chin KJ, Singh K. The superficial ulnar artery-a potential hazard in patients with difficult venous access. Br J Anaesth. 2005; 94(5): 692-693.
16. Pelin C, Zagyapan R, Mas N, Karabay G. An unusual course of the radial artery. Folia Morphol. 2006; 65(4): 410-413.
17. Roca-Tey R, Rivas A, Samon R, Ibrik O, Martinez-Cercos R, Viladoms J. Noninvasive assessment of forearm vessels by color Doppler ultrasonography (CDU) before and after creation of radiocephalic fistula (RCF). Nefrologia. 2007; 27(4): 489-495.
18. Shen S, Hong MK. A rare case of bilateral variations of upper limb arteries: brief review of nomenclature, embryology and clinical applications. Surg Radiol Anat. 2008; 30(7): 601-603.
19. Shetty SD, Nayak BS, Madhav NV, Abhinitha P. The abnormal origin, course and the distribution of the arteries of the upper limb: a case report. J Clin Diagn Res. 2012; 6(8): 1414-1416.
20. Salunke AA, Nambi GL, Dhanwate AD, Siriwardana HA. Superficial ulnar artery: Clinical recommendations to avoid iatrogenic complications due to variation in arterial system. Niger Med J. 2014; 55(3): 276-277.
21. Poteat WL. Report of a rare human variation: absence of the radial artery. Anat Rec. 1986; 214(1): 89-95.
22. Nunoo-Mensah J. An unexpected complication after harvesting of the radial artery for coronary bypass grafting. Ann Thorac Surg. 1998; 66(3): 929-931.
23. Aftabuddin M, Islam N, Jafar M, Hague E, Alimuzzaman M. Management of isolated radial and ulnar arteries at the forearm. J Trauma. 1995; 38(1): 149-151.
24. Devansh MS. Superficial ulnar artery flap. Plast Reconstr Surg. 1996; 97: 420-426.
25. Yuksel M, Yuksel R, Weinfeld AB, Shenaq SM. Superficial ulnar artery: embryology, case report and clinical significance in reconstructive microsurgery. J Reconstr Microsurg. 1999; 15: 415-420.
26. Yazar F, Kirici Y, Ozan H, Aldur MM. An unusual variation of the superficial ulnar artery. Surg Radiol Anat. 1999; 21(2): 155-157.

27. McWilliams RG, Sodha I. Doppler ultrasound of a superficial ulnar artery. Eur J Ultrasound. 2000; 13(2): 155-157.
28. Greene MA, Malias MA. Arm complications after radial artery procurement for coronary bypass operation. Ann Thorac Surg. 2001; 72(1): 126-128.
29. Valantine RG, Modrall JG, Clagett GP. Hand ischemia after radial artery cannulation. J Am Coll Surg. 2005; 201(1): 18-22.
30. Dartnell J, Sekaran P, Ellis H. The superficial ulnar artery: Incidence and calibre in 95 cadaveric specimens. Clin Anat. 2007; 20: 929-932.
31. McCartney CJ, Xu D, Constantinescu C, Abbas S, Chan VW. Ultrasound examination of peripheral nerves in the forearm. Reg Anesth Pain Med. 2007; 32(5): 434-439.
32. D'Costa S, Shenoy BM, Narayana K. The incidence of a superficial arterial pattern in the human upper extremities. Folia Morphol. 2004; 63(4): 459-463.
33. Wood SJ, Abrahasm PH. Bilateral superficial radial artery at the wrist associated with radial origin of a unilateral median artery. J Anat. 1997; 189: 691-693.
34. Sasaki K, Nozaki M, Aiba H, Isono N. A rare variant of the radial artery: clinical considerations in raising a radial forearm flap. Br J Plast Surg. 2000; 53(5): 445-447.
35. Yagain VK, Dave MR, Anadkat S. Unilateral high origin of radial artery from axillary artery. Folia Morphol. 2012; 71(2): 121-124.
36. Lo RN, Leung MP, Lau KC, Yeung CY. Abnormal radial artery in Down's syndrome. Arch Dis Child. 1986; 61: 885-890.
37. Nie B, Zhou Y, Li G, Shi D, Wang J. Clinical study of arterial anatomic variations for transradial coronary procedure in Chinese population. Chin Med J. 2009; 122(18): 2097-2102.
38. Kachlik D, Konarik M, Baca V. Vascular patterns of upper limb: an anatomical study with accent on superficial brachial artery. Bos J Basic Med Sci. 2011; 11(1): 4-10.
39. Natsis K, Papadopolou AL, Paraskevas G, Totlis T, Tsikaras P. High origin of the superficial ulnar artery arising from the axillary artery: anatomy, embryology, clinical significance and a review of the literature. Folia Morphol. 2006;65(4): 400-405.
40. Rodriquez-Niedenfuhr M, Burton GJ, Deu J, Sanudo JR. Development of the arterial pattern in the upper limb of staged human embryos: normal development and anatomic variations. J Anat. 2001; 199(Pt 4): 407-417.
41. Timur AA, Driscoll DJ, Wang Q. Biomedicine and diseases: the Klippel-Trenaunay syndrome, vascular anomalies and vascular morphogenesis. Cell Mol Life Sci. 2005; 62(13): 1434-1447.